



**Burns Cooley Dennis, Inc.**

**Geotechnical and Materials  
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# ***Performance of Permeable Friction Courses***

## **NCHRP 9-41**

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# Presentation Outline

- Definition
- Benefits
- Maintenance
- Rehabilitation
- Performance
- Conclusions

# Definition

- PFCs are OGFC mixes that are specifically designed to have high in-place air voids
  - Air Void Contents greater than 18%

# Benefits of PFCs

- Benefits Were Categorized Based on Three Areas
  - Safety Related
  - Driving Comfort
  - Environmental

# Benefits

## ■ Safety Related Benefits

### – Reduced Potential for:

- Hydroplaning
- Splash and Spray
- Light Reflection (Glare)

### – Improved

- Skid Resistance (Especially During Wet Weather)
- Visibility of Pavement Markings (Especially at Night)

# Benefits

## ■ Safety Related

### – Reduced Wet Weather Accidents

- Virginia SR 23 – Reduced from 39% of all Accidents to 17%
- France A7 Motorway – Number of Accidents Fell from 52 (over 6 yrs) to none (over 4yrs)
- Canada – Reduced 55%
- Austria – No Difference in Dry Weather but “Fewer” Wet Weather
- Japan – 80 % Reduction

# Benefits

## ■ Driver Comfort Related

- Driver Confidence in Rain Events
  - Less Splash/Spray
  - Less potential for Hydroplaning
  - Results in Improved Capacity
- Less Glare at Night on Wet Surfaces
- Better Visibility of Pavement Markings
- Improved Smoothness

# Benefits

## ■ Environmental

- Reduced Tire/Pavement Noise (3-5 dB(A))
- Pavement Smoothness
  - Improved Fuel Economy
- Use of Waste Materials
  - Ground Tire Rubber
  - Fibers



# Benefits

## ■ Environmental

- Improved Quality of Stormwater Runoff from pavement surfaces
- Cool Pavement Option to combat Urban Heat Island

# Maintenance

- Divided into Two Categories
  - General Maintenance
  - Winter Maintenance

# Maintenance

- General Maintenance
  - Cleaning Clogged Surfaces
  - Preventative Surface Maintenance
  - Corrective Surface Maintenance

# Maintenance

## ■ General Maintenance

- Cleaning Clogged PFC
- Should be Started While Still Permeable
  - Not Being Done in US
  - Some Research in Europe
  - Methods

- High Pressure Hose
- Truck Mounted “Suck-Sweep” System



# Maintenance

## ■ Preventative Surface Maintenance

- Fog Seals Have Been Used in the Past
  - Fog Seals will Reduce Permeability
  - Do Not Affect Macrotexture
  - Research In Oregon Concluded that Expected Benefits To Prolong Life Were Not Substantiated.
- Texas Has Used Seal Coats Over Distressed Areas

# Maintenance

## ■ Corrective Surface Maintenance

### – PFCs Can Be Patched

- Small Patches Can Be Made with Dense-Graded Mix
  - Rotate 45 deg. (Diamond Shape) So Water Will Flow Past.
- Large Patches Should Be with PFC
- When Patching, Only a Light Tack Coat Should Be Applied to Vertical Faces

# Maintenance

- Winter Maintenance
  - Each Agency/Paper Describes Different Techniques
  - One Constant – More Deicing Materials Are Needed for PFCs

# Maintenance

## ■ Winter Maintenance

### – Quotes From Literature

- “... no definitive solution for winter maintenance..” Padmos Denmark (2002)
- “...Since the behavior of the road salts on PFC surface is so different, special locally adjusted strategies are needed.” Griebe ISAP (2002)
- “...experience is the only true method of developing a winter maintenance program.” Brousseau et al France 2005



# Maintenance

## ■ Winter Maintenance

- Advantages of PFC (Isenring et al, Switzerland, 1990)
  - Ice does not generally form on wet PFC surfaces
  - High level of macrotexture is beneficial
  - Tendency of ice formation within wheel path covered in snow is reduced due to macrotexture, permeability, and limited thaw.

# Maintenance

## ■ Winter Maintenance

### – Disadvantages (Isenring, et al)

- Need for more deicing salts
- Use of “grit” to improve friction not viable
- Snow and ice tend to stick to PFC sooner because the surface is generally cooler
- Snow and icing rain can form earlier on PFC because deicing salts do not stay on surface
- Preventative salting is not as beneficial
- Some icing problems can occur in initial portion of dense-graded surface (lack of salt transport)

# Maintenance

## ■ Winter Maintenance

### – Iwata et al (2002)

- Monitored Salinity Concentrations on Pavement Surface (Dense-Graded and PFC)
- Concluded That Rate of Decrease in Salinity Concentration Was Generally Less on PFC Surfaces
- Circulation Due to Interconnected Voids and Traffic

# Maintenance

## ■ Winter Maintenance

### – Deicing Salts

- 25 to 100 % more for PFCs (Greibe, 2002)
- 25 to 50 % more (Litzka, 2002) (Austria)
- 30 % more (Giuliani, 2002)
- 100% more in Slovenia (Litzka, 2002)
- 25% more in Netherlands (Litzka, 2002)

### – Why More?

- Different Thermal Properties
- Reaches Freezing Sooner, Stays at Freezing Longer
- Interconnected Voids

# Maintenance

## ■ Winter Maintenance

### – Interesting Observation

- In Italy, A change from a 20 mm MAS to a 16 mm MAS PFC led to a significant improvement in road conditions during winter events.

# Maintenance

## ■ Winter Maintenance

### – Observation

- Pumping Action Caused by Traffic May Circulate Salt Solution Within Void Structure
- May Explain Iwata et al Observation About Salinity Concentration
- Bennert and Cooley (2006) Showed an Influence of Traffic Volume on Friction Test Results – Design Lane = Higher Friction

# Rehabilitation

- Typical Distresses
  - Raveling, Delamination, Cracking

# Rehabilitation

- Minor Rehabilitation Strategies Similar to Dense-Graded Layers
  - Must Maintain Drainage Characteristics
  - Discussed Under Corrective Surface Maintenance



# Rehabilitation

## ■ Major Rehabilitation

- Replacement of Entire Layer
- Mill and Replace with Another PFC or Other Layer
- Georgia Has Expressed Concern with Milling
  - Grooves May Hold Water
  - Investigating Micro-Milling

# Rehabilitation

## ■ Major Rehabilitation

- Inlays Are Not Recommended for PFC
  - Drainage Characteristics
- Overlaying with Dense-Graded Layer Not Recommended
  - Trapped Moisture – Stripping
- Some Success with Hot In-Place Recycling
  - However, No Specific Report found
  - Cited in a Paper

# Performance

- Categories (Huber, 2000)
  - Performance Life – Length of Time Pavement Maintains Its Beneficial Characteristics.
  - Service Life – Length of Time Pavement Maintains Its Frictional Properties and Smoothness
  - Service Life Generally Longer

# Performance

## ■ Service Life

- Vast Majority of Reports/Papers Suggest About 10 years.
- 1998 Survey Indicated 8 years or more
- Friction Not Followed over Service Life
  - Single Reference (Georgia)

# Performance

*Santa, 1997*

Test Section Designation	Friction Number (ASTM E274)			
	10/27/92	11/11/92	4/12/93	2/6/96
Std. OGFC (d)	42	53	52	50
Coarse OGFC (D)	41	50	52	51
D + Mineral Fibers (DM)	39	50	53	49
D + Cellulose Fibers (DC)	37	47	53	49
DC + SB Polymer (DCP)	35	46	52	50
D + SB Polymer (DP)	32	47	51	51
D + 16% Crum Rubber (D16R)	37	48	53	51

PFCs Tend to Have Low Friction Immediately After Construction. When Binder Wears Off, Friction Improves

# Performance

## ■ Service Life

### – Puncher (2004)

- PFCs Deteriorate Slowly for first 5-10 yrs, Then Deterioration Increases

### – Smoothness Seems To Be Most Applicable Problem

- Even Clogged PFCs Maintain High Macrotecture

# Performance

## ■ Performance Life

- Larger MAS Maintain Permeability Longer
- PFCs with Higher Air Void Contents Maintain Permeability Longer

# Performance

- Literature Explicit that PFCs Reduce Tire/Pavement Noise
- 3 dB(A) Most Commonly Cited Reduction in Noise
  - Shown By Sound Intensity, Wayside Measurements, and CPX Trailer
  - Some Researchers Indicated Up To 6 dB(A) Reduction



# Performance

## ■ Performance Life

- No Literature Followed Noise Reduction Over Time
- Thicker Lifts Said To Absorb More Sound
- Macrotexture Seemed More Important Than Permeability In Sound Absorption

# Conclusions

- PFC Layers Have Many Benefits – Mostly Related to Safety
- Design of PFC Contains Four Steps
- Inclusion Within Pavement Design Varies – A Lot Left To Learn
- Construction Similar to SMA
  - Fiber Hoppers and Introduction
  - Draindown

# Conclusions

- Method for Cleaning PFCs Needed
- Work is Needed To Determine Winter Maintenance Guidelines
- Mill and Replace Most Common Rehabilitation Activity
- There Are Specific Limitations That Should Be Considered

*Thanks!*  
*Questions?*



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